Anal Bioanal Chem (2015) 407:8175–8176
DOI 10.1007/s00216-015-9033-3

EDITORIAL

Nanospectroscopy

Mustafa Çulha[1]

Published online: 5 October 2015

Nanospectroscopy simply refers to performing spectroscopy with nanometer spatial resolution. With the emergence of the nanotechnology concept, studying phenomena at nanometer scales has become an important field of research. Spectroscopy studies the interaction of electromagnetic radiation with matter, and to study phenomena at nanometer sizes, it should be confined to the nanometer scale. However, because of the diffraction of light, it is not possible to achieve spatial resolution lower than approximately 200 nm in the visible region of the spectrum. Overcoming the diffraction limit has long been investigated for imaging with optical microscopy, and with the emergence of the nanotechnology concept, use of spectroscopic techniques using electromagnetic radiation to monitor phenomena at a sub-100 nm limit has gained increasing interest.

Being able to monitor molecular phenomena below the diffraction limit may lead to fundamental understandings of many chemical and biochemical molecular processes, which may have a tremendous impact in almost all scientific and technological fields. Among the spectroscopic techniques, vibrational spectroscopy and, more specifically, Raman spectroscopy and its modes can be used to study molecular phenomena at the nanometer scale. With the help of nanometer-size plasmonic structures, it is possible to break the diffraction limit of light, which allows the monitoring of the local environments of these nano-structures. In this context, there is a growing research effort to use tip-enhanced Raman scattering (TERS) and surface-enhanced Raman scattering (SERS) to study phenomena at the nanometer scale. Whereas a tip is used as an enhancement element in TERS, a nanostructured noble metal surface or colloidal particles are used in SERS. The localized surface plasmons of these nanostructures, which are the crucial elements in enhancement of Raman scattering and sensing, help to achieve nanometer-size spatial resolution.

Because a Raman spectrum is like a fingerprint for a molecule or molecular structure, it can be used for label-free detection and identification of molecules and molecular structures. Because it applies to all analytical chemistry fields, the implications of nanospectroscopy in bioanalytical applications could also be enormous. The importance of achieving high sensitivity and spatial resolution becomes more apparent for the detection and identification of biomolecules, biostructures, and organizations in complex biological environments. For example, the detection of an end product of gene expression or drug metabolism in a body fluid can be a challenging task, especially when its concentration is extremely low. When quantification of such analytes is required, it becomes more time consuming and expensive. Currently, realization of such objectives requires extensive use of molecular techniques along with high-cost instrumental techniques, for example mass spectroscopy. As nanospectroscopy evolves, new approaches using it to detect, identify, and quantify biologically relevant molecules and molecular structures in complex samples become more evident.

This topical collection of articles covers instrumentation-related aspects, characterization of nanometer-size biological domains, and biosensing. The review and original research papers in this collection give an insight into recent research efforts in the field. One of the most powerful techniques that can collect molecular fingerprint information at sub-nanometer resolutions is TERS. However, the technique has

Published in the topical collection *Nanospectroscopy* with guest editor Mustafa Çulha.

✉ Mustafa Çulha
mculha@yeditepe.edu.tr

1 Department of Genetics and Bioengineering, Faculty of Engineering, Yeditepe University, Istanbul 34755, Turkey

tip-related disadvantages including low enhancement, stability, and reproducibility. An excellent review addressing tip-related challenges in the use of this technique is included in the collection. Another interesting approach was to use TERS to measure local temperature at nanoscale obtained from the complete Raman spectrum. The report describing resolving of binary self-assembled thiol monolayers with TERS demonstrates the power of the technique for nanospectroscopy applications. Original research papers demonstrating the use of vertical plasmonic dimers for biosensing, a microfluidic paper-based SERS platform for determination of glucose level in blood, and a SERS-based detection of caffeine metabolites and identification of urinary-tract-infection-causing bacteria on the basis of their growth profiles are excellent examples of recent research efforts in the field. In another original research contribution, the local complex molecular environment of gold nanostars in animal skin is demonstrated, which provides clues for the future use of gold nanoplasmonic structures in medicine.

In the future, it is clear that nanospectroscopy will have a substantial impact on the fundamental understanding of nanoscale phenomena. The first to benefit from such advances are bioanalytical applications. It will not only increase the sensitivity for detection of minute amounts of biologically important molecules, but also enable probing and characterization of nanodomain biostructures. The latter might have a special impact on single-cell analysis which aims to reveal cellular bioprocesses in a single living cell.

The relevance of nanospectroscopy is also highlighted by the European COST Action MP1302 Nanospectroscopy, which aims at building a network of European expertise on all aspects of the topic. It currently unites nearly 200 experts from research and industry in over 30 countries. The Action aims at promoting UV/vis/NIR and Raman nanospectroscopy with (ultra-)high spatial, temporal, and spectral resolution and sensitivity, their application to novel (hybrid) organic and inorganic materials and nanostructures, and the modelling of light-matter interaction at the nanoscale. For information on the Action and how to join, visit http://cost-nanospectroscopy.eu/.

I would like to thank all authors for submitting their valuable work for this topical collection. I would also like to acknowledge the contributions of referees. It would not be possible to achieve such a high quality without their careful review and constructive criticisms. Finally, I would like to thank to the Editorial Office and Editors for their friendly and timely support.

Mustafa Çulha is a full professor at the Genetics and Bioengineering Department of Yeditepe University, Istanbul. He is the founder and head of the Nanobiotechnology and Molecular Engineering Group (http://nanobio.yeditepe.edu.tr) there. His current research interests include elements from chemistry, medicine, material science, photonics, and nanoscience and nanotechnology. He has authored more than 70 papers in refereed international journals, several book chapters and patents in the field of analytical and bioanalytical chemistry and nanotechnology. He is also on the editorial board of Applied Spectroscopy.